Using Dynamic Audio Feedback to Support Peripersonal Reaching in Visually Impaired People

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ABSTRACT
Blind children engage with their immediate environment much less than sighted children, particularly through self-initiated movement or exploration. Research has suggested that providing dynamic feedback about the environment and the child's actions within/against it may help to encourage reaching activity and support spatial cognitive learning. This paper presents an initial study suggesting the accuracy of peripersonal reaching can be improved by the use of dynamic sound from both the objects to reach for and the reaching hand itself (via a worn speaker) that changes based on the proximity of the hand to the object. The demonstration will let attendees try the interaction and feedback designs.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: *Social Issues* - Assistive technologies for persons with disabilities

General Terms
Design, Human Factors.

Keywords
Sound perception; reaching; visual impairment.

1. INTRODUCTION
Children who are congenitally or early blind can be less engaged with objects in their immediate environment [5], due to a lack of awareness of the object locations and a slower development of object existence/permanence [8]. Providing a means with which the child could, of his/her own accord, learn of the existence of objects, and their own position relative to them, could encourage more self-initiated movement [5,8] and so improve or expedite spatial cognitive learning. A computer-based system that can control the playing of environmental sounds based on the child's activity could provide more engaging feedback to encourage the child to be "more active against the world" [8]. Environmental sound may also be a way to support the development and performance of accurate reaching in peripersonal (arms-reach) space. Little research has looked at peripersonal reaching accuracy in visually impaired people [3,6]. As environmental sounds can encourage reaching [5,9] and wrist-based sound can improve spatial movements [2], we are investigating whether the combination of environmental sounds and wrist-based sound can improve reaching in blind and visually impaired people. As a first step, we ran an initial study with blind and visually impaired young adults (aged 18 to 19) to determine which of several audio designs best supports accurate reaching. We measured reaching accuracy and subjective responses about the feedback designs, including preferences and whether the sounds created a connection between the hand and the object. The research aim was supported by a focus group with 5 blind and visually impaired young adults (aged 18-19) who said that using external sounds to encourage and support reaching behaviours would be of benefit to blind children.

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2. FEEDBACK DESIGNS
Three feedback designs were compared: 1) a dynamic Geiger counter [4], 2) dynamic increasing pitch (utilising perceptual *streaming* [1]) and 3) a constant (unchanging) design. The first two designs changed dynamically based on the proximity of the hand to the (target) object, while the constant design played continuously and remained the same regardless of proximity. We wanted to measure the effect of feedback emanating from the object alone, the wrist alone and both the object and wrist combined, and so each feedback design had two aspects: an *Individual*, single speaker design and a two-speaker *Coalescent* design. Based on perceptual streaming [1], the feedback designs changed in a way that, at a distance, the hand and object may be perceived as separate, but as proximity increases, they may be perceived as a single source, increasing the association of hand to object. All the sound designs used synthetic "pluck" tones (similar to a guitar string) generated in Audacity. These sounds have an onset of 0ms and rapid decay to increase localisation accuracy [7].

2.1 Geiger Counter
In this design, a pluck tone of pitch C^5 (523.25Hz) was played with increasing temporal frequency as the hand approached the object. The sound was produced by either the object or wrist during the *Individual* speaker design, depending on the condition. The inter-tone delay decreased from 900ms at 50cm distance to 100ms (10Hz) at 7.5cm distance, decreasing 100ms for every 5cm advance (Table 1). The two-speaker *Coalescent* design was similar, but the pluck tones alternated between playing on the object and the wrist and both tones played when touching the object. To increase the perceptual distinction, the object used the C^5 tone and the wrist played a G^4 (392Hz) tone.

Table 1: The mapping of Geiger inter-tone delay (ITD) and Pitch to the distance of the hand to the target object.

Distance (cm)	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**7.5**
ITD (ms)	900	800	700	600	500	400	300	200	100
Pitch Note	C^4	C^4	D^4	E^4	F^4	G^4	A^4	B^4	C^5

2.2 Increasing Pitch
Rapid notes close in pitch are grouped into a single perceptual stream, while notes distant in pitch are perceived as two separate streams [1]. Therefore, the *Individual* design played the 8 tones in a C major scale that increased in pitch from C^4 (261.63) up to C^5 (523.25Hz) as proximity increased (Table 1), at a temporal frequency of 10Hz. A discrete mapping was chosen over a continuous function to provide perceptually clear changes and to provide

potentially more pleasant feedback (harmonious musical steps and feedback that was not continuously changing). For the *Coalescent* design, both the object and wrist speakers played tones at the same 10Hz rate, but played alternately, resulting in a frequency of 20Hz. In this case the object always played the highest C^5 tone and the wrist tone increased based on proximity as in the *Individual* design, so that the tones matched when touching the target.

2.3 Constant Design

The constant audio design was a continually playing repetition of the target object sound: the C^5 pluck tone repeated at a constant 5Hz. It either played from the target object, the wrist or both the object and the wrist. When both the object and wrist played, the tones were alternated at 10Hz, like the Geiger counter.

3. INITIAL EXPERIMENT

The setup consisted of 7 small speakers (weight 50g) connected to a Windows 8.1 PC via USB soundcards and a Microsoft Kinect v2 depth camera, which tracked the position of the participant's hand and the speakers to be reached for. Six of the speakers (KitSound Mini Buddy "Magic 8 Ball") were used as the target objects and positioned as shown in Figure 1. An "Owl" variant of the same model was used for the wrist speaker, attached by a rubber strap.

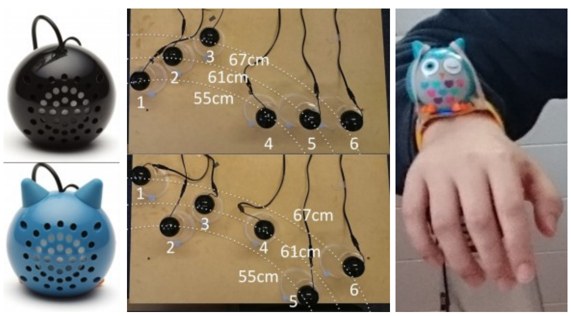

Figure 1: Left: Speakers used in experiment. Middle: Target speaker layouts 1 (top) and 2. Right: speaker worn on wrist.

The experiment had a 3 (Feedback Design) x 3 (Object, Wrist, Both Speakers) within-subjects design, plus a Control condition where only the initial target sound was played (silence thereafter). The 10 conditions were completed over 60 minutes in a random order and the speaker layout (Figure 1) was alternated between conditions to reduce learning effects. In a condition, each object speaker was the "target" to be reached for 3 times in a random order, following 6 practice trials. At the start of each trial the "target" object was indicated by five C^5 pluck tones played at 5Hz. The participant then reached for the target with the right hand. To "select" a speaker, the participant placed the palm of their right hand on top and pressed a keyboard key with the left hand.

Table 2: Mean reaching error (wrong speaker) and time.

	Wrist	Object	Both	Geiger	Pitch	Constant	Control
Error (%)	21.3	17.2	14.6	12.4	13.1	27.7	32.2
Time (ms)	3643	3372	3723	4049	3203	3478	2655

3.1 Initial Results

The results indicated a benefit of using dynamic feedback, compared to constant or no feedback. Objective measurements of reaching (Table 2) suggested that dynamic sounds led to significantly more accurate reaching, and sounds from reachable objects were more likely to help fast reaching than sounds from the wrist or from both the object and wrist together. When asked which of the audio designs they preferred, one participant had no preference, one preferred the Geiger counter, but three preferred the Pitch design. None preferred the Constant design. When asked why, the participant that preferred the Geiger counter said it was because he thought the changes in sound based on proximity were more "intuitive" than the changes in pitch, as people who are not musical may struggle to make use of the pitch changes. He, and another, also believed dynamic changes were "necessary" to help reaching accuracy, as the Constant design was unhelpful. In contrast, one of the participants who preferred the Pitch design believed it to be the more intuitive design, while the others preferred Pitch because the changes were more obvious, easier to distinguish and so more helpful. All designs were "pleasant" (> 4), with the Dynamic designs being slightly more so than the Constant.

Table 3: Mean Likert responses for the three Feedback Design questions. 1 = "Strongly Disagree", 7 = "Strongly Agree".

Question	**Geiger**	**Pitch**	**Constant**
"The sounds created a connection between the hand and the object"	6.2	6.2	4.4
"The combination of the hand and object speakers was beneficial"	3.6	3.4	3.0
"The sound was pleasant"	5.6	5.4	4.6

Table 3 shows the average responses for three questions asked about each *Feedback Design*. Both of the Dynamic designs produced a connection between the hand and the object, much more than the Constant design. This may help young children create an internal connection between his/her movements and the environment, potentially increasing the sense of agency and willingness to engage with nearby objects. Providing sounds from both the wrist and object did not really provide any benefit over one speaker alone, and two participants expressed that having sounds coming only from the wrist made reaching more difficult than having it from the object or from both.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

[1] Bregman, A. *Auditory Scene Analysis.* The MIT Press, Cambridge, MA.

[2] Cappagli, G., Baud-bovy, G., Cocchi, E., and Gori, M. Audio and proprioceptive space perception in sighted and visually impaired children. *Proceedings of IMRF 2014*.

[3] Macé, M., Dramas, F., and Jouffrais, C. Reaching to sound accuracy in the peri-personal space of blind and sighted humans. *Proceedings of ICCHP 2012*, pp 636–643.

[4] McGookin, D., Brewster, S., and Priego, P. Audio bubbles: Employing non-speech audio to support tourist wayfinding. *Proceedings of HAID 2009*, pp 41–50.

[5] Millar, S. *Understanding and Representing Space: Theory and Evidence from Studies with Blind and Sighted Children.* Oxford Press, Oxford.

[6] Parseihian, G., Jouffrais, C., and Katz, B. Reaching nearby sources: comparison between real and virtual sound and visual targets. *Frontiers in Neuroscience 8*, Sept. 2014, Article 269.

[7] Rakerd, B. and Hartmann, W. Localization of Sound in Rooms, III: Onset and Duration Effects. *Journal of the Acoustical Society of America 80*, 6, pp 1695–1706.

[8] Ross, S. and Tobin, M. Object Permanence, Reaching, and Locomotion in Infants Who Are Blind. *Journal of Visual Impairment & Blindness 91*, pp 25–32.

[9] Wishart, J., Bower, T., and Dunkeld, J. Reaching in the dark. *Perception 7*, pp 507–512.